



NASA CONNECT™

Breaking Barriers: Solving Linear Equations©

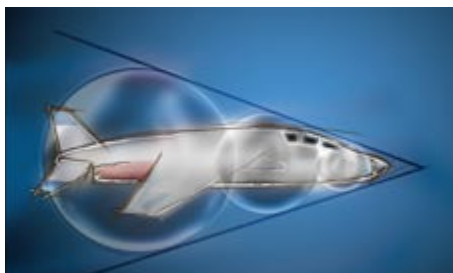
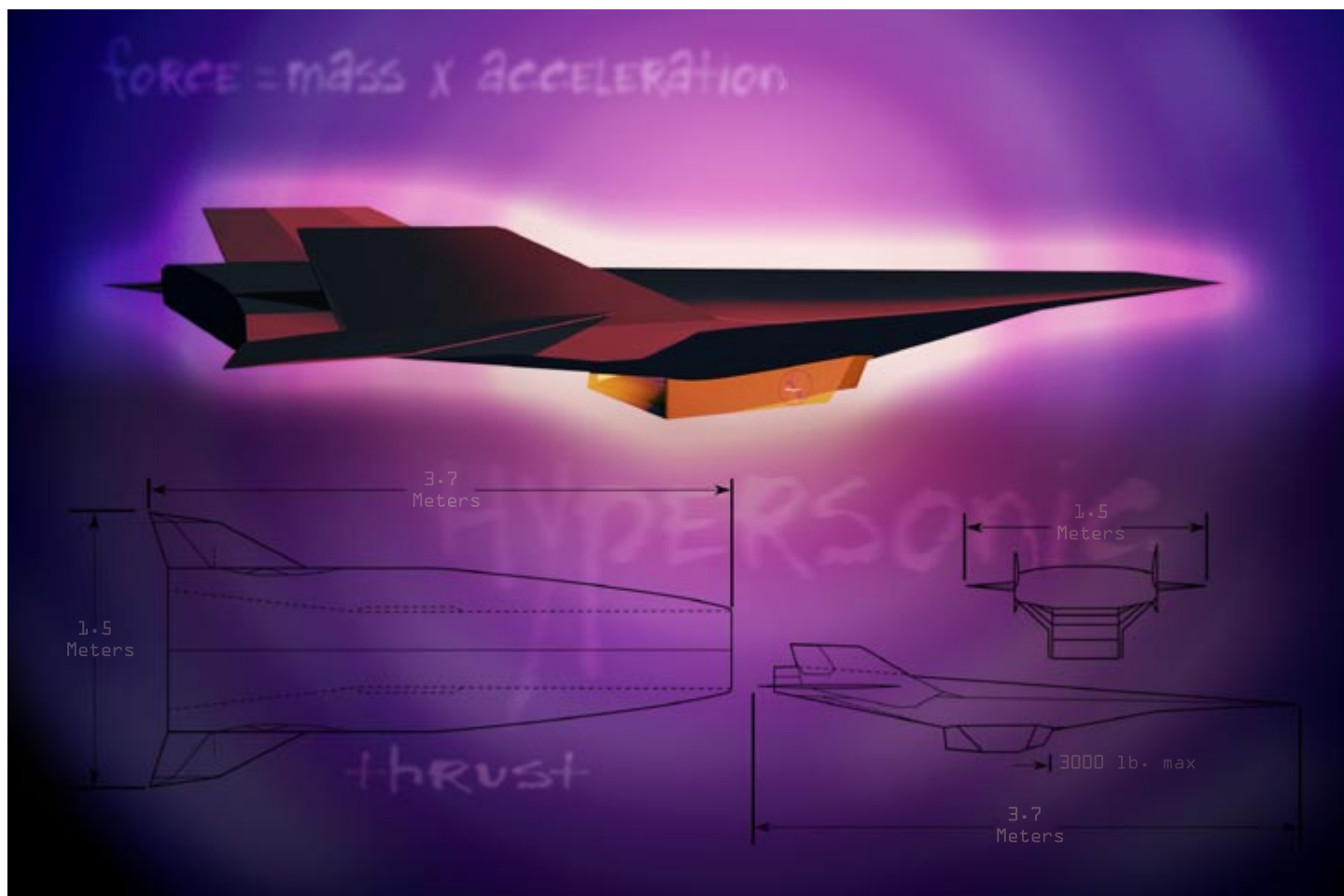
An Educator Guide with Activities in Mathematics, Science, and Technology

Educational Product

Educators

Grades 6-8

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NASA CONNECT™

Breaking Barriers: Solving Linear Equations®

An Educator Guide with Activities in Mathematics, Science, and Technology

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Hands-On Activity

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Registered users of NASA CONNECT™ may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail nasaconnect@aiaa.org.

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Program Overview

SUMMARY & OBJECTIVES

In this episode of NASA CONNECT™ Breaking Barriers: Solving Linear Equations®, students learn about supersonic aircraft while investigating the nature of science. They look at how NASA researchers continue to modify their work as powerful machines are being built that push hypersonic records to Mach 10 and beyond. NASA engineers and scientists use algebraic equations to help build models that will fly faster, longer, and higher. By conducting inquiry-based and web activities, students connect NASA research with the mathematics, science, and technology they learn in their classrooms.

Student Involvement

Inquiry-Based Questions

Host, Derek Wang, NASA engineers, and scientists will pose inquiry-based questions throughout the program. These questions allow the students to investigate, discover, and think critically about the concepts being presented. When viewing a videotape or DVD version of NASA CONNECT™, educators should pause the program at the designated segments so students can answer and discuss the inquiry-based questions. During the program, an icon will appear on the screen to indicate the appropriate time to pause the tape or DVD.

Teaching Note: *It is recommended that you preview the program before introducing it to your students so you will know where the pause points occur.*

Hands-On Activity

The web-based activity is teacher-created and is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science Education Standards (NSES), and the International Technology Standards of Education (ITEA). Students collect data after launching the Balloon X-1 aircraft which they design. The data are used to calculate the average speed of the balloon. The average speeds are then graphed and students look for patterns that could be used to make predictions about the speed of their aircraft over a greater distance.

Squeak Web Activity

The hands-on activity is teacher-created and is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science Education Standards (NSES), and the International Technology Standards of Education (ITEA). The interactive Squeak web activity is designed to help students plot the data they take during the hands-on activity. They can set up the scales for their graphs, enter their data and plot the data by moving points to the proper place on the graph paper created by Squeak. Once the students have finished plotting, they can check their graphs to see if they have plotted the points in their data table correctly.

Resources

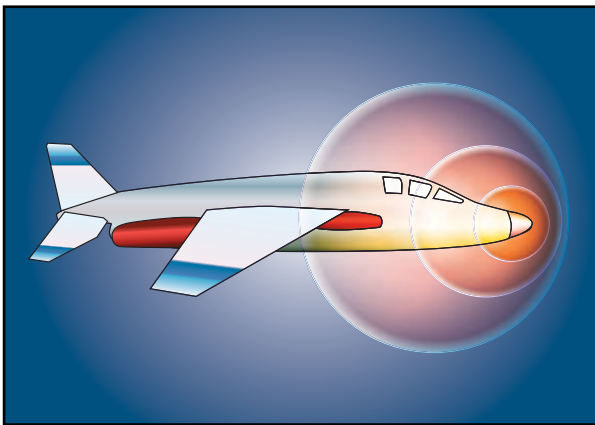
Teacher and student resources may enhance and extend the NASA CONNECT™ program. Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. For additional resources visit the NASA CONNECT™ web site, <http://connect.larc.nasa.gov>. Inclusion of a resource in this educator guide or on a web site does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Student Activity

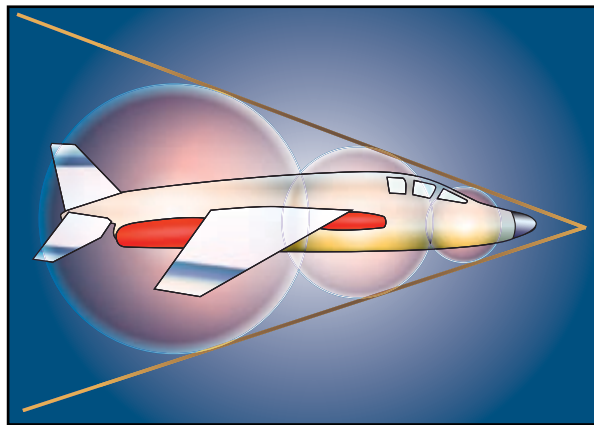
Background

The “X” designation, originally “XS” for eXperimental Supersonic, was given to a family of experimental aircraft built solely for flight research. The first series of X-planes was built by The National Advisory Committee for Aeronautics (NACA), the predecessor to the National Aeronautics and Space Administration (NASA). X-planes have been used to test factors such as speed, wing and tail design, fuselage length, landing gear, rocket power, adjustments for high altitude and speed flight, maneuverability, and pilot control.

Traveling as fast as the speed of sound was once thought to be impossible. People believed that a physical barrier, the sound barrier, would prevent any craft from becoming supersonic. Pilots who attempted to fly near the speed of sound experienced unexpected conditions: increase in drag, loss of lift and control, and violent shaking. Sound travels about 343 meters per second or about 767 miles per hour at sea level and 20 C°. It travels a little faster through warm air than through cold air. Sound travels four times faster in water and faster still through solids such as wood or steel. When an aircraft travels through air, it produces sound waves. If the craft flies faster than the speed of sound, the sound waves begin to pile up into a wall of sound in front of the craft. As the aircraft passes through the wall, an abrupt pressure change takes place, creating a shock wave known as a sonic boom. The sound heard on the ground may be loud enough to break windows. The X-1 was the first plane to fly faster than the speed of sound. The historic flight made on October 14, 1947 by pilot Charles (Chuck) Yeager, set new boundaries for high speed flight, proving that a sound barrier does not really exist.



As an aircraft travels at the speed of sound, it begins to overtake the sound waves which pile up in front of the aircraft.



When the aircraft moves faster than the sound waves can travel, a massive shock wave is formed, creating a sonic boom which can be heard on the ground.

Today aircraft are categorized by the range of speed as they travel through our atmosphere. Mach numbers are used by aeronautics researchers to describe the speed a plane is flying. The Mach number is calculated by dividing the speed of an object by the speed of sound. Mach 1 is equal to the speed of sound at the temperature and altitude where most planes fly, or about 1,225 kilometers per hour (761 miles per hour). Subsonic (below Mach 1) is the slowest speed, ranging from a fast run to the speed jets fly just below the speed of sound. Sonic, or transonic speeds (Mach 1) are those which are equal to the speed of sound. Supersonic speeds are speeds up to Mach 5 or five times the speed of sound. Finally hypersonic speeds are those speeds above Mach 5.

$$\text{Mach Number} = \frac{\text{Object Speed}}{\text{Speed of Sound}}$$

Hypersonic



Mach > 5.0

Supersonic



Mach > 1.0

Sonic



Mach = 1.0

Subsonic



Mach < 1.0

The X-43A made aviation history when a scramjet engine was tested in November, 2004. During its third and final flight, the X-43A research vehicle flew at a record breaking Mach 9.6, or about 11,265 kilometers (7,000 miles) per hour. The X-43A more than doubled the top speed of the fastest air-breathing crewed vehicle, the jet powered SR-71. Although crewed flights with scramjet engines may be some years away, engineers continue to move toward this goal.

In the normal jet engine, the air is compressed by moving parts. In a ramjet engine, a stream of air is compressed by the forward speed of the aircraft itself. The scramjet, or supersonic combustion ramjet, is a unique design concept that combines the air-breathing technology of a ramjet with the ability to scoop up air at supersonic speeds, creating a supersonic airflow through the engine. Ground tests of scramjet powered vehicles have shown the potential for speeds of at least Mach 15, but no flight tests have yet surpassed the X-43A Mach 9.6 flight.

Aeronautics is the science of flight. People who study aeronautics learn about how and why aircraft fly. To help them make better designs, engineers and scientists use the computation and measurement tools needed to solve math and science problems. By collecting all kinds of data and using those data to make a working model, engineers can turn an idea into the real thing. Wind tunnel testing and flight simulations play an important role in this design process. Modern computer graphics present data in three-dimensions, giving researchers the ability to analyze large quantities of complex information, enabling them to quickly draw conclusions from their data. In spite of these advances, researchers may spend years working on a single aircraft design or modifying the previous designs, as with the X-planes. Mistakes are treated as opportunities to learn and questions often lead to new, more complex questions that demand answers.

Instructional Objectives

Students will:

- understand the design process.
- collect and record a variety of data.
- make a model and design improvements based on data collected.
- calculate speed using time and distance measurements.
- identify linear relationships.

National Standards

NCTM Mathematics Standards:

Algebra

- Understand patterns, relations, and functions.
- Represent and analyze mathematical situations and structures using algebraic symbols.
- Use mathematical models to represent and understand quantitative relationships.
- Analyze change in various contexts.

Measurement

- Apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data.

NSES Science Standards:

Unifying Concepts and Processes

- Evidence, models, and explanation
- Change, constancy, and measurement
- Form and function

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science and Technology

- Abilities of technological design
- Understandings about science and technology

History and Nature of Science

- Science as a human endeavor
- History of science

ITEA Standards:

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 9: Students will develop an understanding of engineering design.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

NASA Relevance

NASA's Aeronautics Research Mission Directorate develops tools and technologies that help transform how the air transportation system operates, how new aircraft are designed and manufactured, and how our Nation's air transportation system can reach unparalleled levels of safety. NASA engineers and scientists work with industry partners and other government agencies to make aviation history.

NASA researchers have worked for decades to demonstrate scramjet technologies, first in wind tunnels and computer simulations, and finally in actual flight. Applications of these technologies include hypersonic airplanes, reusable launch vehicles, or even hypersonic missiles. Compared to a rocket-powered vehicle, like the Space Shuttle, scramjet (supersonic combustion ramjet) powered vehicles promise more airplane-like operations for increased affordability, flexibility, and safety for ultra high speed flights within our atmosphere and into low Earth orbit. Because they do not have to carry bulky oxygen tanks, as rockets must, vehicles powered by air-breathing scramjets can be smaller and lighter and may one day replace one or more stages in rocket design.

Preparing for the Activity

Student materials – per group

assorted balloons, including large size, helium-quality balloons
10 meters fishing line
1 drinking straw
1 sheet of graph paper per student
colored pencils
journal
stapler
masking tape
meter stick
stop watch
scissors
1 glider pattern per student
protractor
3 metal washers
30 cm string
calculator
1 clip clothespin
markers or crayons (optional)
Student Handouts

Linear equation – an equation whose graph is a straight line

Mach number – the ratio of the speed of an object to the speed of sound

Scramjet – an engine with few moving parts that scoops up air at supersonic speeds

Sonic – the speed of sound or about 1, 225 kilometers per hour

Subsonic – speeds that range from a slow run up to the speed of sound

Supersonic – speeds that range from the speed of sound to Mach 5 or almost five times the speed of sound

Wavelength – the distance between the same points of two successive waves

Vocabulary

Altimeter – tool for measuring altitude

Design process – the collection of data that leads to the development and testing of a working model

Frequency – the number of sound vibrations per second measured in Hertz (Hz)

Hypersonic – any speed greater than Mach 5 or about 6,125 kilometers per hour

Time:

30 minutes for NASA CONNECT™ show

30 minutes for Engage activity

60 minutes for Explore activity

The Activity

Brief Lesson Description

Students build and test a model of a Balloon X-1 and calculate the average speed of the model. Data are collected and the data points are graphed. Students look for patterns that could be used to make predictions about the speed of their aircraft and to make modifications that will allow the Balloon X-1 to fly faster or longer.

Video Component

View NASA CONNECT™ Breaking Barriers: Solving Linear Equations© and answer all inquiry-based questions.

Engage

Teaching Note: *Real-world situations that can be modeled by linear functions occur more often than those modeled by any other type of function. Algebraic thinking involves creating tables from the input/output data collected, graphing these ordered pairs, and searching for patterns. Once a pattern is discovered, a rule is formulated to fit the data and tested against all available data. Some relationships will be proportional (the straight line will pass through the origin of the graph) while others are non-proportional, but still represent linear functions*

The cost for long distance telephone minutes, temperature conversions from Fahrenheit to Celsius, the ratio of your height to your shadow, or the number of nickels and dimes that add to exactly one dollar are all linear functions. Average speed (when remaining constant) is also a linear function.

Conduct the following demonstration to introduce students to average speed.

1. Fill a large graduated cylinder with light corn syrup.
2. Ask one student to be the official timekeeper and one student to be the recorder.
3. Drop a marble into the graduated cylinder.
4. Begin timing the descent of the marble after it passes the first increment line. (This is to give the marble time to reach a constant speed.)
5. Mark the times the marble reaches different marks on its way to the bottom of the cylinder.
6. Determine the distance the marble descended to each mark and record the time. Be sure to deduct the initial distance prior to marking time.
7. Calculate the average speed of the marble while moving between the marks by using the equation: $\text{average speed} = \text{distance traveled} / \text{time taken}$. Use the difference in time between each mark and the distance moved between each mark.
8. Repeat the activity three more times.
9. Compare the average speeds between each set of marks and for each trial.

Discuss the following questions:

1. How did the average speeds between the marks compare?
2. How did the average speeds for each trial compare?
3. What do you think would happen if you dropped the marble in a container that was twice as large?
Three times as large?
4. What would a graph of these data look like?
5. Why do we use line graphs to display some types of information?
6. What can we learn about the relationship of the ordered pairs by looking at the graph?
7. What does a straight line on a graph tell us?

Teaching Note: *You may wish to discuss the difference between a proportional linear function and a non-proportional linear function. If a relationship is proportional, the line will pass through the origin of the graph.*

Assign Journal Write # 1:

Discuss the marble activity. Explain what you learned about average speed. Why is the graph linear?

Try dropping the marble in other liquids. Discuss any changes you see on the graph.
Is the relationship still linear? Why?

Explore

Teaching Note: *Students should work in groups of 5-7 students for this activity as the balloon launch will require teamwork.*

1. Allow each student to select 2 – 3 balloons of different sizes.
2. Ask the students to predict which balloon will provide the most thrust for their Balloon X-1.
3. Trace the balloons onto 1cm graph paper.
4. Calculate the area of each balloon.
5. As a group, compare your results with your teammates.
6. Choose the balloon your team wants to test.

Assign Journal Write # 2:

How can the area of each flat balloon guide your predictions of the amount of thrust each balloon will provide for your glider? Describe another way you could compare the amount of air the balloons will hold.

Teaching Note: *There may or may not be a direct relationship between the area of the balloons and the amount of air the balloon will hold. In this activity, students should look for patterns.*

7. Have students build and test their Balloon X-1 aircraft. (*See Student Handouts*)
8. Ask students to capture data in multiple ways: using illustrations, recording numbers, taking photographs.

Technology Insertion Point: *Students may want to produce a digital journal that includes photos that have been uploaded or scanned, comments, questions, and notes.*

9. Record the times the Balloon X-1 crossed the 1-meter, 2-meter, and 3-meter marks.
10. Using a colored pencil, ask students to plot the time and distance data on a line graph.
11. Remind the students the equation for average speed is the distance traveled divided by the time taken:

$$\text{Average Speed} = \frac{\text{Distance}}{\text{Time}}$$

12. Have each group calculate the average speed for the Balloon X-1 aircraft.
13. Use the average speed calculations to make predictions about the distance traveled at greater times. (*How far would the Balloon X-1 travel in 12 seconds if it did not run out of thrust?*)
14. Make an input/output chart that will show the relationship of distance to time using the average speed calculations. For example:

If your average speed were 0.6 meters/second:

Time	Distance
1 Second	0.6 meters
2 Seconds	1.2 meters
5 Seconds	3.0 meters
10 Seconds	6.0 meters
20 Seconds	12.0 meters

15. Using a different colored pencil, plot these average speed data points on the line graph.
16. Compare these averages to the actual data plotted on the student graphs.
17. What kind of a pattern is evident in the graphs? Are the functions linear?

18. Discuss why the student graphs may be different. (*Students often think that because stopwatches will record times to the nearest ten thousandth of a second, they must be more accurate, but forget to consider the reaction time of the person operating the stopwatch. As the balloons lose air, they will begin to slow down so the average speed is no longer constant. The more times the balloon is blown up and the air released, the less elastic the balloon becomes which also affects the balloon speed.*)

19. Using the altimeters students created, change the angle of incline for the launch path and conduct the test again.

20. Compare the average speed for different launch paths.

Technology Insertion Point: *Students may wish to use a graphing calculator or computer program to graph their results. You may also have your students use the Squeak activity to plot their data. Students using this technology can independently check their graphs, giving you more time to assist those students who are having difficulty plotting their data. Compare the computer-generated graphs to student-made graphs.*

Assign Journal Write # 3:

What kind of a pattern do you see in the data you collected?

Assuming the Balloon X-1 did not run out of air and enough thrust was provided to maintain an average speed, use your data to calculate the amount of time it would take the Balloon X-1 to travel 4-meters. 5 meters. 10 meters.

Explain

Newton's third law of motion tells us that every action has an opposite and equal reaction. Once the end of the balloon is released, the air inside is forced out through the small opening or nozzle. The balloon moves forward in the direction opposite the flow of air. The wings help stabilize the Balloon X-1, just as wings help stabilize actual aircraft. The drinking straw acts as the fuselage, or body of the aircraft. By threading the fishing line through the straw, the path of the aircraft can be controlled and easily measured.

A mathematical function consists of three parts:

- A set of input numbers
- A set of output numbers
- A rule that assigns a unique output number to each input number.

The output depends on the input. In other words, the output, or distance traveled in this case, is a function of the input, or time traveled.

The average speed of an object is the function of the distance traveled divided by the time taken:

$$\text{Average Speed} = \frac{\text{Distance}}{\text{Time}}$$

If the average speed remains constant, the average speed can be graphed as a linear function. To make predictions about longer distances, the speed must remain constant.

By recording the time the Balloon X-1 takes to travel three specific distances: 1-meter, 2-meters, and 3-meters, three sets of data points or ordered pairs can be graphed. The graph for these three points should be close to a straight line because the Balloon X-1 is moving at a fairly constant speed. As the balloon loses air (thrust), it will slow down. For the purpose of this activity, students are only looking at a finite set of data and using those numbers to make predictions. If students continued to take measurements until the balloon stopped, the data would show that the average speed of the balloon had slowed and the graph would no longer be linear.

Human reaction time may significantly impact test results. Many students believe that a stopwatch is automatically accurate because it records time to the nearest ten thousandth of a second. To help compensate for reaction times, round the times to the nearest tenth of a second.

Journal Write # 4

How did the angle of the launch path affect the speed of your Balloon X-1? What would your findings mean to engineers trying to design a vehicle that could travel into outer space?

Evaluate

Create a rubric that assesses the students' calculations, creation of the Balloon X-1 model, and their responses to questions.

Ask students to use the data they have collected and what they have learned about the speed of sound to create a Mach number for their Balloon X-1 flight. Students should thoroughly explain in writing the mathematical calculations and the process they used to create the number.

Extend

1. Modify your Balloon X-1 design. What can you do to make it fly longer or faster? Share your new design with your classmates.
2. Create a time line of X-plane history. Include pictures of the designs and facts about each one. Show how these experimental aircraft have changed over the years.

Technology Insertion Point: *The time line may be created as a computer slide presentation.*

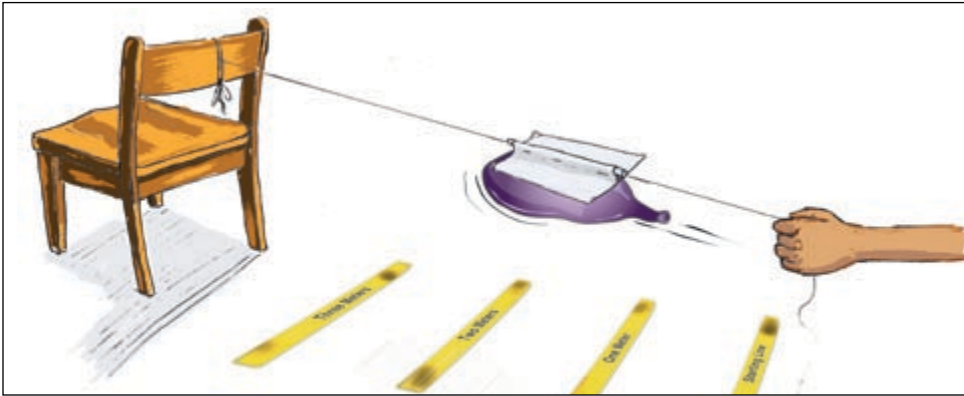
3. Make poster biographies of the men and women who have played an important role in designing and flying supersonic aircraft. You might include Charles (Chuck) Yeager, Scott Crossfield, Jacqueline (Jackie) Cochran, or Ernst Mach.
4. Make a model or diagram that would show the difference between a ramjet and a scramjet engine.
5. Conduct some research to learn about the phenomena that occur when an aircraft travels faster than the speed of sound. Explain what the sound barrier actually is and how it can be “broken”.
6. Find out more about human reaction times. Visit the NASA SCI Files™ web site at <http://scifiles.larc.nasa.gov>. Click on the link for episodes and guides and find The Case of the Great Space Exploration. Conduct the experiment, “The Quickest Hand in the West” on page 82-83 of the Educator Guide.

Student Handout**Balloon X-1 Directions**

1. Cut out the glider pattern. You may use markers or crayons to decorate your glider wings.
2. Fold the glider wings as directed on the pattern.
3. Attach the drinking straw to the center of the glider.
4. Cut a strip of fishing line approximately 10 meters long.
5. Tie the end of the line to a stable point, such as a door knob or chair.

This will be your Balloon X-1 launch path.

6. One student should firmly hold the unsecured end of the string in a straight line.
7. Using masking tape on the floor beneath the launch path, mark a starting line.
8. Measure one meter from the starting line and use masking tape to mark it.
9. Measure and mark two meters and three meters from the starting line.

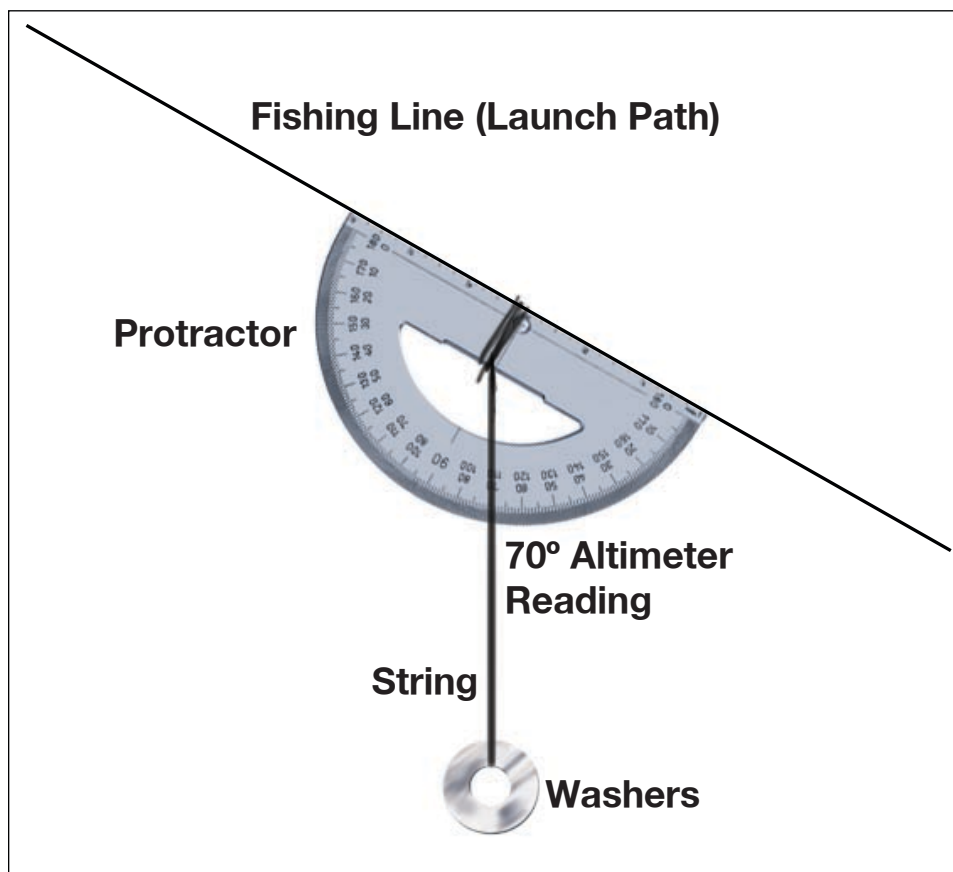


10. Thread the other end of the fishing line through the drinking straw.
11. Blow up the balloon you have chosen to test.
12. Use masking tape to attach the glider wings and straw fuselage to the inflated balloon.
13. Be sure the open end of the balloon is facing away from the finish line (in the opposite direction you wish the balloon to travel).
14. One student should twist the open end of the balloon and clip securely with a clothespin to make sure no air escapes until the balloon is released.
15. Line up the Balloon X-1 at the starting line.
16. Use the altimeter you made to measure the angle of the slope of the launch path (fishing line).
17. Record the angle of the incline (or slope) of the launch path on your data sheet.
18. Position team members with stopwatches at the 1-meter, 2-meter, and 3-meter marks.
19. When given the signal, the person holding the Balloon X-1 will release the end of the balloon, allowing the air to escape.
20. At the same time, the three timekeepers should start their stopwatches.
21. As the Balloon X-1 crosses each marked distance, the assigned timekeeper should stop his or her stopwatch.
22. On your data sheet, record the times that the Balloon X-1 crossed each marked distance, to the nearest tenth of a second.
23. Taking into consideration human reaction time and group dynamics, you may need to try this several times to get the most accurate data, and you should develop a consistent approach for starting and stopping the watches.
24. Plot the data points for time and distance traveled on graph paper.
25. What kind of pattern do you see?
26. Launch your Balloon X-1 again using a different angle of incline (slope) for the launch path.
27. Compare your new results. How did the angle of the path affect the speed of your aircraft?

Student Handout

Altimeter Directions

1. Cut a piece of string 30 cm in length.
2. Turn the protractor upside down.
3. Tie one end of the string to the center of a protractor. Some protractors have a hole or eye in the center to help with alignment.
4. Attach three washers to the other end of the string.
5. Line up the bottom (flat side) of the protractor along the launch path.
6. The string should hang down to measure the angle of incline for the launch path. (see diagram)
7. Be sure to use the correct number for the angle.
8. A horizontal path will have a 0 degree of incline, but will show a 90 degree altimeter reading.
This is because the launch path is perpendicular to the ground.
9. A vertical path will have a 90 degree incline, but will show a 0 degree altimeter reading.
Your angles should be between 0 and 90 degrees.



Student Handout**Time Trials****First Balloon X-1 Trial**

Distance (m)	Time (tenths of a second)	Average Speed = $\frac{\text{Distance}}{\text{Time}}$	Altimeter Reading

Second Balloon X-1 Trial

Distance (m)	Time (tenths of a second)	Average Speed = $\frac{\text{Distance}}{\text{Time}}$	Altimeter Reading

Third Balloon X-1 Trial

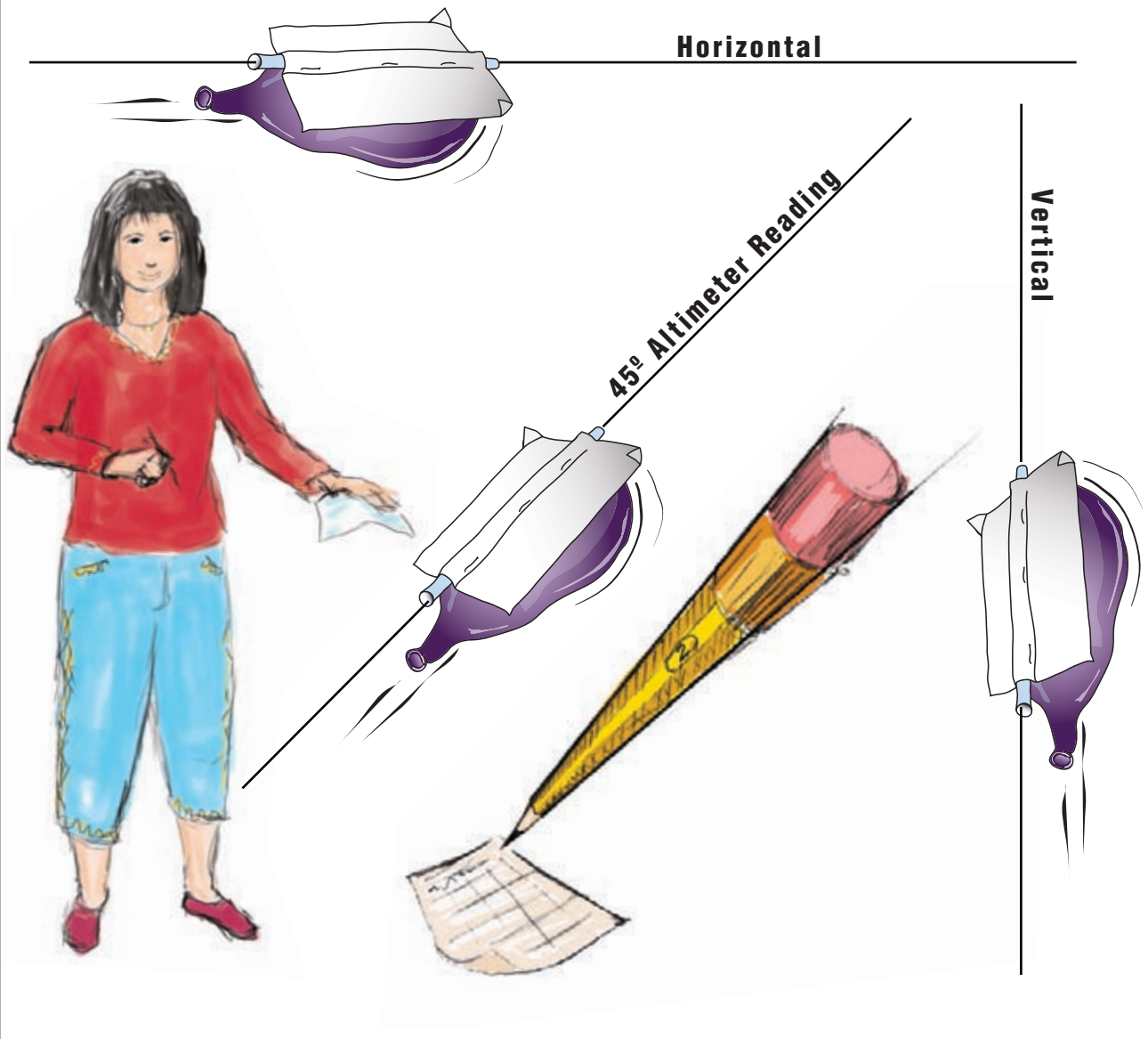
Distance (m)	Time (tenths of a second)	Average Speed = $\frac{\text{Distance}}{\text{Time}}$	Altimeter Reading

Student Handout

Balloon X-1

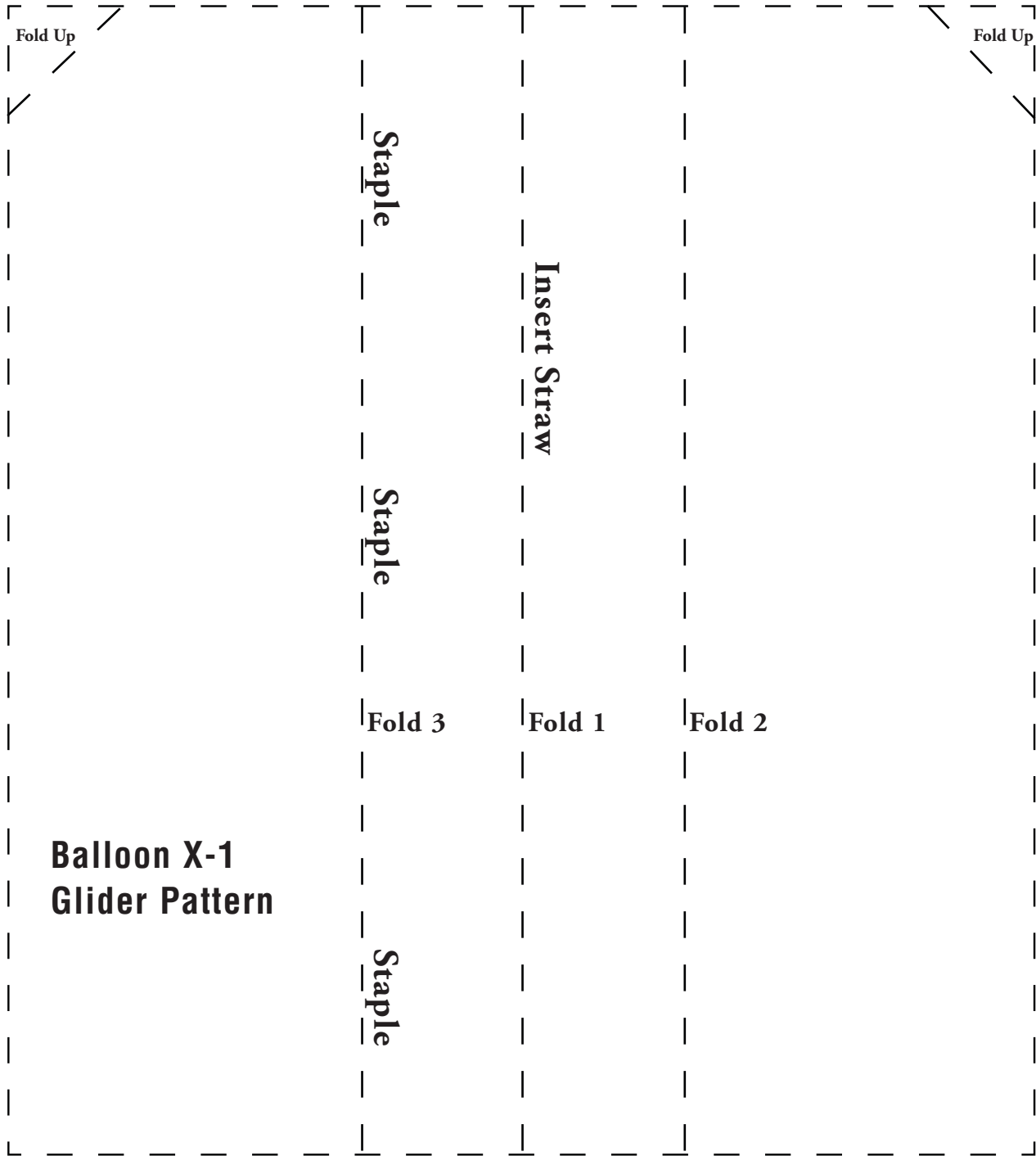
Altimeter Reading vs. Distance Traveled

	Balloon Size	Distance Traveled		
		Horizontal 90° Altimeter Reading	____° Altimeter Reading	Vertical 0° Altimeter Reading
1.				
2.				
3.				
4.				
5.				



Student Handout

Balloon X-1 Glider Pattern



Student Handout

Journal Writes

Journal Write # 1

Discuss the marble activity. Explain what you learned about average speed. Why is the graph linear?

Try dropping the marble in other liquids. Discuss any changes you see on the graph. Is the relationship still linear? Why?

Journal Write # 2

How can the area of each flat balloon guide your predictions of the amount of thrust each balloon will provide for your glider? Describe another way you could compare the amount of air the balloons will hold.

Journal Write # 3

What kind of a pattern do you see in the data you collected?

Assuming the Balloon X-1 did not run out of air and enough thrust was provided to maintain an average speed, use your data to calculate the amount of time it would take the Balloon X-1 to travel 4-meters. 5 meters. 10 meters.

Journal Write # 4

How did the angle of the launch path affect the speed of your Balloon X-1? What would your findings mean to engineers trying to design a vehicle that could travel into outer space?

Resources

Books

Atkins, Jeannine: *Wings and Rockets: The Story of Women in Air and Space*. Farrar, Strauss, and Giroux, 2003, ISBN: 0374384509.

Breathed, Berkeley: *Wish for Wings that Work: An Opus Christmas Story*. Little, Brown, & Company, 1995, ISBN: 0316106917.

Gardner, Robert: *Light, Sound, and Waves Science Fair Projects Using Sunglasses, Guitars, and Other Stuff*. Enslow Publishers, Inc., 2004, ISBN: 0766021262.

Harkins, Susan Sales: *Breaking the Sound Barrier: The Story of Chuck Yeager*. Mitchell Lane Publishers, Inc., 2005, ISBN: 1584153989.

Maynard, Christopher: *I Wonder Why Planes Have Wings and Other Questions about Transportation*. Houghton Mifflin Company, 2003, ISBN: 0753456621.

Ross, Wilma: *X-15 Rocket Plane*. Silver Burdett Press, 1994, ISBN: 0896868311.

Stille, Darlene: *Waves: Energy on the Move*. Compass Point Books, 2005, ISBN: 075651259X.

Sweetman, Bill: *Supersonic Fighters: The F-16 Fighting Falcons*. Capstone Press, 2001, ISBN: 0736807926.

Videos

NASA's Center for Distance Learning: *NASA CONNECT™, Future Flight Equation (2000)*
Grades 6 – 8

NASA's Center for Distance Learning: *NASA SCI Files, The Case of the Challenging Flight (2002)*
Grades 3 - 6

NASA's Center for Distance Learning:
Destination Tomorrow™ Program 4: "Behind the Scenes – Hyper X" (2001)
Grades 7 – Adult

NASA's Center for Distance Learning:
Destination Tomorrow™ Program 19: "How It Works – Hypersonic X-43 Aircraft" (2005)
Grades 7 – Adult

NASA's Center for Distance Learning: *NASA SCI Files™, The Case of the Barking Dogs (2000)*
Grades 3 - 6

Discovery Channel: *The Phenomenon of Sound (1997)*
Grades 6 – 12

Disney Educational Productions: *Bill Nye, the Science Guy: Waves (1995)*
Grades 3 – 8

Nova: *Battle of the X-Planes (2003)*
Grades 7 to adult

Nova: *Supersonic Dream (2005)*
Grades 7 to adult

Tom Snyder Productions: *Science Court: Sound (1997)*
Grades 3 - 7

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Web Sites

NASA Dryden Flight Research Center Photo and Movie Archive Gallery

<http://www.dfrc.nasa.gov/Gallery/>

NASA Langley Hyper-X

<http://www.nasa.gov/missions/research/x43-main.html>

NASA's Hyper-X Multimedia Animations, Demonstrations, and Downloadable Glider Kit

<http://lisar.larc.nasa.gov/LISAR/BROWSE/hyperx.html>

NASA Explores: Hyper X: Greased Lightning

http://www.nasaexplores.com/show2_article.php?id=02-031

NASA Fact Sheet: Sonic Booms

<http://www.nasa.gov/centers/dryden/news/FactSheets/FS-016-DFRC.html>

NASA Facts: Scramjets and Ramjets

<http://www.nasa.gov/centers/dryden/research/HyperX/ramscram.html>

NASA: What is a Scramjet?

http://www.nasa.gov/missions/research/f_scramjets.html

How Stuff Works: What Causes a Sonic Boom?

<http://science.howstuffworks.com/question73.htm>

Nova: Faster than Sound

<http://www.pbs.org/wgbh/nova/barrier/men.html>

X-Planes Site

<http://users.dbscorp.net/jmustain/xpmain.htm>

Flying the Hyper Skies

<http://www.sciencenewsforkids.org/articles/20040407/Note3.asp>

Global Aircraft: Fact sheets on the X-43 and others

http://www.globalaircraft.org/planes/x-43_hyper-x.pl

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